

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Development of Emotional Game Mechanics through the use of Biometric Sensors

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Mestrado Integrado em Engenharia Informática e Computação

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July of 2017

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ABSTRACT

Every year gamers demand more from new games and thus arises the need to better immerse the player in the games. There are already ways to do this, namely by using virtual reality or motion controllers, that immerse the player in a visual or physical (i.e. using movement) experience respectively, however this doesn't cover the emotional aspects of the player, which can be measured in terms of valence and arousal and together can cover a wide range of emotions (i.e. happiness, stress, fear, etc.). It is believed that these emotions can be detected in the player and used to adapt the game he is playing thus improving his overall game experience. In fact, analysis and use of emotional content in multimedia experiences is becoming more and more popular and multiple videogame companies are investigating its versatility (e.g. Sony, Valve, etc.). Nonetheless the use of these tools is neither optimal nor practical.

This dissertation's main goal is to develop a system capable of monitoring player emotions and explore different game mechanics that use biometric signals with the goal of improving the player's gaming experience. Specifically, there is the aim to develop a low-cost method of processing biometric signals usable in real-time and to study the effects of said mechanics in the affective experience. Furthermore, we want to study in the context of affective game what are the best approaches in terms of gameplay adaptation.

To this end, we developed a game that uses the player's physiological input to control different game mechanics, which we used as a proof of concept. The game included five emotional mechanics that we used to improve the player's gaming experience. The study involved 12 participants and determined that reading the player's emotions adapting the game in real time and is not only feasible but also useful in improving the gaming experience.

Acknowledgements

I would like to start by thanking my family for all the support and love that helped me become who I am today, and who were always present in times of need.

I am also grateful for the moments spent with my friends who I know I can always count on for help, a good laugh and a drink after a long day.

Lastly, I want to give a special thanks to Ana Moura, for her help, for always making me laugh and for putting up with all my nonsense.

David Caminha

“Before we start, however, keep in mind that, although fun and learning are the primary goals of all enrichment center activities, serious injuries may occur”

-GLaDOS, Portal

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Abbreviations and Acronyms

AV	Arousal-Valence
BVP	Blood Volume Pulse
ECG	Electrocardiogram
EEG	Electroencephalogram
EMG	Electromyography
EOG	Electrooculography
GSR	Galvanic Skin Response
HR	Heart Rate
RSP	Respiration
SC	Skin Conductance
TMP	Temperature

1. Introduction

1.1. Context

Videogames have become one of the world's favourite forms of entertainment, creating hours of enjoyment for millions of people worldwide. In fact, according to recent data from the Entertainment Software Association, 63% of US households have at least one person who plays videogames 3 or more hours per week (ESA 2016). These statistics are indicative of the potential market and explain the amount of 16.5 billion US dollars spent in video and computer games in 2015 in the US alone.

Players are constantly demanding more immersive experiences which propelled a major number of breakthroughs in many scientific fields such as: computer animation, artificial intelligence, physics simulation, interaction techniques among others. This gave developers and designers new tools to create immersive environments, however to keep improving we need to focus our efforts in promising yet lacking areas of the gaming experience.

The general opinion is that people play games for one of two reasons: to live a fantasy or to relax from the problems of their daily life. In both cases we can recognise a common trait: videogames must provide an experience that enables players to immerse themselves in the virtual world.

The concept of immersion appeared for the first time with the creation of virtual reality systems referring to how enveloped in the virtual world the user was. Over the years it's overuse by the general public and the academic community generated various interpretations and definitions. However, one aspect in particular is common among these variations: the emotions. Throughout many games and accounts of players' experiences emotions are highly valued as either strong reactions to game events (scares, scenery or challenge) or a bond towards the game (empathy with the character or plot), they are indeed signs of a good experience and regarded in many works as essential for achieving the highest levels of immersion.

1.2. Motivation

The study of systems that can recognize, interpret, process and simulate human emotions, or affective computing is gaining popularity and revealing many

practical applications. Adapting any aspects of affective computing can in fact unlock a range of potential applications from more human-like artificial intelligence to dynamic multimedia experiences or emotional management systems.

Gamers often complain that the game's "replayability" has decreased over the years. This can be justified by the increasing complexity, production and time costs that it represents. Being able to create human adaptive content, meaning that the content would continuously adapt to the user's evolution over time, could relieve the developers in some costs and ultimately provide consumers more content for their money.

As mentioned before, consumers buy videogames to immerse themselves in a virtual world. Any method that would aid in this process will be definitely well accepted and add value to the overall experience not to mention it would act as a competitive edge for the developing company.

Designers always aim to convey a certain affective experience with the available graphical and auditory stimuli. If they were to delegate the choice of stimuli to a mechanism that monitors the user's emotional state then it would allow them to focus on other game aspects and simply define rules for the system regulating the affective experience.

1.3. Goals and Outline

As such, our goals with this dissertation, will be to design a way of processing physiological signals, followed by using this information in different game mechanics with the goal of improving the player experience and analysing the impact of these mechanics on the player.

We will start by conducting an analysis of how emotions work and how we can determine a person's emotional state from their physiological response and an overview on the work done on videogames using player's emotions. Following this part, we will discuss the use of fuzzy logic for modelling player's emotions. Finally, we will present the game we created, as well as, how the game mechanics interact with the player's emotions and the results of the case study.

2. People, Emotions and Immersion

2.1. Emotions

When it comes to understanding how emotions can be recognized we have to look into the nervous system. In humans, it is divided into the Central Nervous System and the Peripheral Nervous System, which is further divided into the Somatic Nervous System and the Autonomic Nervous System (Netter 1997).

The Autonomic Nervous System is responsible for involuntary body actions such as glandular activity, cardiac and digestive control to name a few. Among these are a number of physiological mechanisms that can be tied to emotions like respiratory, cardiovascular and sudation functions.

The definition of emotions by the Oxford Dictionary is: “a strong feeling deriving from one’s circumstances, mood, or relationships with others”. However, many authors suggest their own definition of emotions (Emotion, 2017).

Ekman, for example, defines them as an automatic process influenced by our past experiences. It happens when something that can affect our well-being is happening and sets in motions a series of physiological responses to deal with the situation (Ekman 2003). Whereas Ortony, Clore and Collins place emotions as reactions to events, agents or objects, that one evaluates according to the way the situation is presented and interpreted (Ortony, Clore, & Collins 1990).

While some consensus is found in the definitions of emotions it is important for us to differentiate them from prolonged emotional states, also known as moods, since emotions are discrete events that can happen in milliseconds and emotional states are prolonged and slow-changing representing the overall emotional tendency.

From the collection of definitions of emotions in the literature Nogueira draws three conclusions supporting the feasibility of emotion recognition methods (Nogueira, 2015):

- Emotions are fundamentally equal to all human beings, meaning it is possible to infer what emotions are felt by monitoring physiological changes;
- The correlations in the literature suggest equal emotional states generate the same physiological response across subjects, therefore a method of measuring emotional states is generalizable;
- Emotions derive from our physiology and mental state which is

affected by our environment and interactions, which indicates we can influence what emotions the user feels.

2.2. Immersion

As mentioned before immersion is one of the key concepts required for a successful game. However, it has taken various definitions since its first appearance. For Slater, immersion defines the degree to how faithfully the experience is simulated and can lead to a sense of presence representing the player's "*sense of being there*" (Slater 1994).

More recent works on immersion include this sense of presence in the definition and consider the psychological aspect of immersion the major one in reaching high immersion levels, while input fidelity is regarded as a lesser factor aiming to help players make the transition between the real and virtual worlds (Brown & Cairns 2004; Ermi & Mäyrä 2005).

In these definitions emotions are considered as vital aspects for the immersive experience. Seen as the means to create empathy with the game characters and the narrative, they are described as the main obstacles to achieve the final stages of immersion (Brown & Cairns 2004) or just a way that players relate to as being "*in the game*" (Jennett et al. 2008), emotions are undeniably present when it comes to achieving immersion.

Ermi and Mäyrä also study the relation between emotions and immersion and propose a model containing three categories of immersion: sensory, challenge-based and imaginative (Figure 1), where emotions are a crucial factor in the latter.

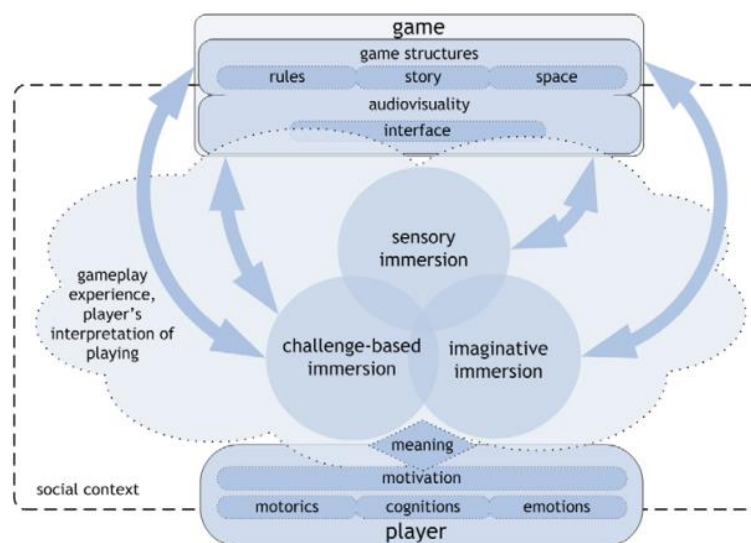


Figure 1 – SCI-model as created by Ermi & Mäyrä

In their work, Ermi and Mäyrä also analyse the levels of immersion reported by the users in a series of popular videogames concluding that imaginative immersion was higher in games that presented interesting characters and narratives, which goes in line with the theory that empathy and emotions play an important role in immersion. This experiment also revealed that imaginative immersion was the least present of the three categories in the tested games, proving that this is still an underexplored area in games (Figure 2).

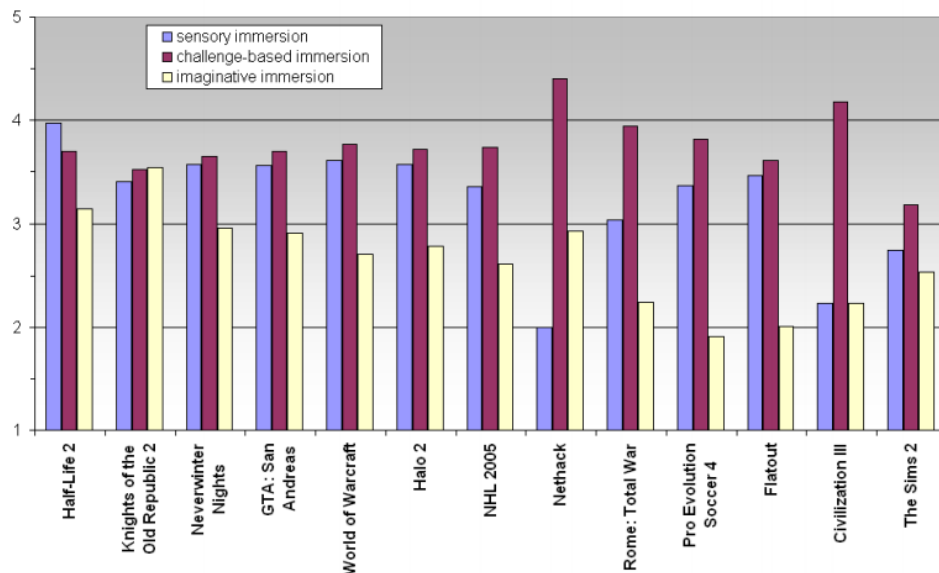


Figure 2 – Amount of each immersion dimension reported by players in various popular digital games

Having noted that videogames generate involuntary reactions that are perceived as emotions, we now must ask ourselves: “*What emotions are evoked on the players? How do they affect them?*”

Ravaja et al. provide some answers to these questions by conducting a series of tests with 37 participants in four different games (Ravaja et al. 2004), concluding that the games produce different emotional patterns that affect a certain scope of emotions (an action game will create emotions of fear and anger while a puzzle game will be associated with relaxation). Although the authors noticed emotions associated with negative feelings in one game they also reported it being highly immersive which means both positive and negative emotions have the potential of achieving high levels of immersion.

Games are indeed designed to be as emotionally charged as possible, creating a scary or emotionally heavy environment, presenting impressive scenery or fast-paced gameplay are only a few of the tricks used by game designers to do this. However, each person is different and reactions to events will vary from one individual to another, thus it is impossible to cater to each one’s needs. Monitoring players’ reactions in real-time would allow us to model emotional reaction profiles that can be used to dynamically create future game

events. This would allow us to influence the player's emotional response in order to optimize the user's immersion level.

2.3. Reading Emotions with Biofeedback

To create the models mentioned in the previous section we need to look at the different approaches available. Yannakakis and Togelius suggest three main methods of modelling players' experience: Subjective, Objective and Gameplay-based (Yannakakis and Togelius 2011). With these techniques, the authors attempt to define how the player affectively reacts to the gaming experience.

2.3.1. Subjective Modelling

Subjective Player Experience Modelling (SPEM) is the most direct way of modelling the affective experience. By directly asking the user to report on their affective experience we can obtain rich information on the player's affective state (Yannakakis and Togelius 2011). However not only the information is hard to analyse but it is also prone to experimental noise due to player learning or self-deception. Another issue is that this type of approach is highly intrusive if done during gameplay and can suffer from players' memory limitations if done at the end of a gaming session.

2.3.2. Objective Modelling

Objective Player Experience Modelling (OPEM), on the other hand, explores the link between emotions triggered by game events and the physiological responses they generate on the player. This technique uses multiple modalities of player input to model the user's affective state including electrocardiography, galvanic skin response, respiration and electromyography to name a few (Yannakakis and Togelius 2011). As the authors point out OPEM can be divided into model-based, model-free and any mix of the two approaches. Model-based OPEM refers to the creation of emotional models based on emotion theory mapping dimensions such as arousal and valence to specific emotional states as can be seen in Russell's arousal-valence space (Figure 3). Model-free OPEM, on the other hand, is the construction of a mapping based on user annotated data. Hybrid approaches can commonly be found allowing authors to build their own emotional model while basing themselves on existing theoretical models for their structure.



Figure 3 – Russell's arousal-valence space

Many studies can be found exploring the correlations between physiological reactions and the emotions felt by users. Chanel et al. for instance successfully determine arousal using a fusion between electroencephalogram and peripheral physiological signals which included galvanic skin response, blood pressure and heart rate, respiration and thoracic movements and temperature (Chanel et al. 2005).

Leon et al. propose the use of auto associative neural networks in conjunction with data from skin resistance, heart rate and blood volume pressure to determine valence successfully distinguishing emotional states in users (Leon et al. 2007).

Boxtel is able to distinguish a number of facial muscles involved in different emotions noting particularly that the corrugator supercilii (brow) and zygomaticus major (cheek) can be used to determine valence. The corrugator response indicating a negative linear relationship and the zygomaticus a positive curvilinear relation (Boxtel 2010).

Kim and André detect emotions generated by music in participants by detecting and analysing arousal and valence levels through the use of several biosensors: electromyography, skin conductance, electrocardiogram and respiration (Kim & André 2008).

Silva et al. work to create aeronautical simulations aided by emotion recognition tools in 2009 (Silva et al. 2009). In their work the user's galvanic skin response, respiration and temperature were used to determine the arousal and valence states and then adjust the simulation variables. An important factor in

their work was the use of minimal-invasive and real-time emotion assessments which allowed to make adjustments to the simulation. The study however lacks the use of other physiological measures to account for more scenarios.

2.3.3. Gameplay-based Modelling

Gameplay-based Player Experience Modelling (GPEM) is based on the premise that every action made by the player in an interactive environment is reflective of their affective state and can therefore be used to model the affective state (Yannakakis and Togelius 2011). The data retrieved from the gameplay sessions can then be analysed using some existing model or emotion theory or similarly to objective PEM using player annotated data. The authors also note that while being the least intrusive method and computationally efficient it usually results in low-resolution models of the player's experience since it is an approach based on several strong assumptions.

In our opinion and in the aim of this work we feel that an objective approach is definitely needed since it seems to be the best way to model users' affective experiences in real-time with sufficient accuracy and minimal intrusiveness. Moreover, from the aforementioned studies, skin conductance, heart rate and electromyography seem to be the sensors of choice due to low costs and intrusiveness. We envision the use of these sensors in our own work for emotion detection while basing ourselves in previous works.

2.4. Biofeedback in Games and Affective Gaming

Game developers are always on the lookout for the next way to improve their game and distance themselves from the competition. Biofeedback gaming has been on the horizon for a while now with notable industry giants investing into its research such as Valve with some biofeedback game prototypes (Ambinder 2011), new controllers in Sony's tests for DualShock 4 (Loveridge 2013) and Xbox Kinect 2.0's capability of optical heart rate detection (Narcisse 2013).

In the academia biofeedback techniques are referred to as affective gaming which, similarly to other terms used, have various definitions varying from author to author. Gilleade et al.'s ACE model is one that lays the foundations for how the player's emotional state should be used to adapt the gaming experience. ACE stands for "assist me", "challenge me" and "emote me" (Gilleade, Dix, & Allanson 2005).

The first heuristic is meant to guarantee the player doesn't get stuck and indicates the game should provide help if the player feels frustrated.

The second one will prevent the player from feeling bored while playing

presenting the player with a challenge, such as spawning more enemies or augmenting the game's difficulty.

Lastly, "emote me", represents the emotional stimulation that the player receives according to the designer's intentions.

Hudlicka also provides insight to how to create affective gameplay by specifying a set of requirements he deems necessary (although out of reach at the time) for an affective game engine (Hudlicka 2009):

- Recognize a wide range of emotions in the player;
- Representation of the player's emotions through affective user models;
- Adapting gameplay aspects and character behaviours to said emotions;

It is important for us to note that not all biofeedback games are affective games. An example of this can be the use of the player's chest volume or respiration to influence the character's aim. This example would be considered a biofeedback game but not necessarily an affective game since it is not the player's emotions that are interacting with the game. If, on the other hand, the player would be unaware of this fact then one would understand that the interactions and the game's experience itself would be completely different.

Biofeedback game mechanics can in fact be divided into two categories: direct and indirect physiological input (Nacke et al. 2011). This refers to the type of control the player holds over the input, for instance the player cannot control his heart rate or sudation functions but can control respiration and muscle contraction. Kuikkaniemi et al. find this categorisation is incomplete and propose a second dimension in terms of player awareness by categorising biofeedback mechanics as implicit or explicit (Kuikkaniemi et al. 2010).

As suggested by Nogueira each quadrant may have benefits and some applicability but there is a need for defined rules when using each type of biofeedback (Nogueira 2015). In sum, direct biofeedback should be used for simple mechanics with easy to understand controls, while indirect biofeedback should be reserved for complex adaptations and prevent the user from easily manipulating it. Explicit biofeedback should be reserved for noticeable alterations in the gaming experience while implicit biofeedback should adapt "*behind the scenes*" aspects such as enemy artificial intelligence.

Several works can be found using biofeedback techniques to adapt game mechanics (see Table 1). These works usually look into how the created mechanics influence the player's experience and some report what adaptations are preferred.

Nacke et al. do a comparative study presenting the use of direct and indirect physiological input mechanics. In their work, the authors use a variety of biometric signals to adapt the game in different ways. Players had to play the

game in different conditions, two using biofeedback and one without biofeedback and results showed they preferred the game when using biofeedback. One important aspect to note is that players also reported that when the game adaptations were controlled through direct biofeedback the game was more enjoyable (Nacke et al. 2011).

Remembering what we discussed previously we can imagine the fact that no implicit and explicit distinction was made (every mechanic was explicit) could have biased the participants choices regarding their favourite mechanics, while they may have enjoyed the direct control more it may not be appropriate for some mechanics to have direct control regarding design principles and game balance.

Kuikkaniemi et al. explore this concept of implicit biofeedback in their work to discover that explicit biofeedback was more successful in creating a better immersive experience (Kuikkaniemi et al. 2010). They postulate that the “*wow factor*” from biofeedback can be a reason for this and explain their concern in creating mechanics that not only provided value but did not disturb the game’s balance, which may lead us to think that implicit biofeedback may be more indicated for balancing and guaranteeing the game’s logical sequence in terms of emotional content is optimal.

Negini et al. provide us with very interesting insight with their work by adapting three distinct components of a game: the player’s character, the non-playable characters (NPC), in their case enemies, and the environment. This allowed them to shed some light onto a very important question of affective gaming: “*What adaptations bring more value to the game?*”. They found out that both the player and environment adaptations were good while the NPC’s adaptation resulted in reduced enjoyment for the players, concluding that players prefer to be given the tools to overcome an obstacle rather than reducing the difficulty of the game (Negini et al. 2014). Unfortunately, this work was limited in terms of biometric sensors and limited itself to a specific genre and mechanics.

Dekker and Champion a great example of affective biofeedback games studying the use of players’ heart rate and skin conductance to modify a level from Half-Life 2. The work used a horror setting since it would be the most likely to cause a high emotional response and created several game adaptations to test whether or not they improve the game’s experience. By running a test with a control group whose game was not adapted by biofeedback the authors were able to determine that the biofeedback mechanics were indeed successful in creating a better experience. However, they also reported some balancing issues among other small problems like player’s past knowledge of the game and the need to learn how to use the new mechanics that may have influenced the data collected.

This topic not only interests the academic community but also industry giants like Valve. Their work as presented by Mike Ambinder on some of their most popular games can also help identify some advantages and pitfalls of affective game mechanics.

The work on Left4Dead considers how the difficulty and “*behind the scenes*” aspects of the game can be influenced by skin conductance. Thus, helping understand how optimal arousal patterns could be achieved by modelling the player’s emotional state, while simultaneously creating a better experience.

Alien Swarm’s adaptation created a relax to win condition which could prove counter intuitive and create feedback loops or unexpected manipulations. This work raised more questions than the answers it provided but is nonetheless an interesting starting point for more experiments on the topic.

Reference	BF Type	Adaptations	Game Genre	Sensors
(Nacke et al. 2011)	indirect & direct	Movement speed, jump power, enemy size, weapon range, weather conditions, boss speed, petrifying gaze	2D side scrolling shooter	RSP, GSR, ECG, TMP, Eye gaze
(Kuikkaniemi et al. 2010)	indirect & direct	Movement, shooting, character shaking	FPS	SC, RSP, EMG
(Negini, Mandryk & Stanley 2014)	indirect	Player speed & ammo; enemy speed & number; weather and item rarity	FPS (Half-Life 2)	GSR
(Dekker & Champion 2007)	indirect	Movement, hearing, audio-visual effects, damage modifiers, game difficulty	FPS (Half-Life 2)	HR; SC
(Ambinder 2011)	indirect	Enemy spawns; Item placement; In-game encounters	FPS (Left4Dead)	SC
	indirect	Timer countdown rate	TDS (Alien Swarm)	SC
	direct	Aiming	Puzzle Platform (Portal 2)	Eye gaze

Table 1 – Review of biofeedback games

In Portal 2 the player's eye gaze was used to control where to aim while the mouse controlled where to move. While this did not include emotion manipulation also resulted in an engaging biofeedback mechanic.

In every study, the authors reported increased immersion and overall enjoyment from the participants. Some studies delve deeper and suggest which mechanics or game components should be adapted and how to best do it. Nevertheless, some issues remain as these are merely suggestions requiring more testing and in most of the works the aspect of game balancing was left aside or considered an issue.

3. Fuzzy Logic and Biofeedback

Fuzzy logic is a way of representing some variable's value by a descriptive term, just as a human would (Cox, 1992). These systems tackle the imprecision of variables by expressing said variables in linguistic terms (e.g. low, medium, high). To get these descriptions variables are passed to membership functions which in turn define the degree of membership of a variable to each term. Finally, "If/Then" rules are the way responses are generated in relation to the variable's linguistic definition, instead of using mathematical formulas that can be quite complex at times. Since we have noisy input signal, the physiological variables are continuous and they can be described using language it seemed logical to use a fuzzy logic approach. Furthermore, we wanted to use the simplest solution and avoid complex mathematical calculations since one of the goals is that creating emotional mechanics should be easily transferred to the industry.

3.1. Recent work

Many recent studies have used fuzzy logic to model a player's emotional state, Mandryk and Atkins, for example, successfully used GSR, ECG and EMG signals to model players emotions during a gaming period using fuzzy logic (Mandryk and Atkins, 2007). They achieved this by creating the membership functions from 6 participants and later using these functions in a fuzzy system that modelled the player emotions from 6 other participants through their physiological input. With these membership functions and a set of rules the authors were able to deduce the player's arousal and valence levels and through them the player's emotional state (boredom, fun, frustration, challenge, happy, calm) during a game of NHL 2003, a sports game. Their work has great significance to our study as we intend to create a similar system.

Another study uses EEG data from individuals in conjunction with fuzzy rules and membership functions to classify emotions (Matiko, Beeby and Tudor, 2014). This study focuses more in proving that positive and negative emotions correlate with the activation of the left and right brain hemisphere. Nonetheless, it validates the usage of a fuzzy logic approach to model user emotions.

A third work focuses on analysing engineers' emotions during computer aided design activities to determine if a correlation exists between the tasks and the emotions felt (Liu et al., 2014). The authors used EEG, GSR, EMG, EOG and HR (derived from ECG) to measure psycho-physiological signals, which were then taken as input parameters by the fuzzy system to determine the valence and arousal of participants. The authors study demonstrates how psycho-physiological signals can be used to better understand engineers' emotion state, while also underlining the importance of emotions in human decision making.

In the work of Orero et al. the goal was to determine the player's emotional state from their physiological signals in order to compare the variations with the game's narrative. To do so they recorded the player's GSR and HR and used those values in conjunction with fuzzy decision trees which created the rules mapping signals to game episodes.

Since the creation of a fuzzy system was not in the scope of our thesis we based our work on the work of Mandryk and Atkins who conducted a very similar study to the one we wish to carry out (Mandryk and Atkins, 2007). The following sections will explain the most important point of the fuzzy system and how they were used.

3.2. Membership functions

Fuzzy membership is the way we determine the degree of membership of our input variables. In our case we have GSR, HR and EMG as our input variables, which we will categorize from "very low" to "very high". As mentioned before the membership functions were inspired on a previous work (Mandryk and Atkins, 2007) and will allow us to verify something they did on their work, which is that we can create the membership functions from a base population and later use them with different individuals to read their emotion state. As such our membership functions started off as the functions Mandryk and Atkins created on the first part of their work and were tweaked throughout the game's alpha testing as to adapt the functions to the type of game since it was slightly different from the game used in the aforementioned study.

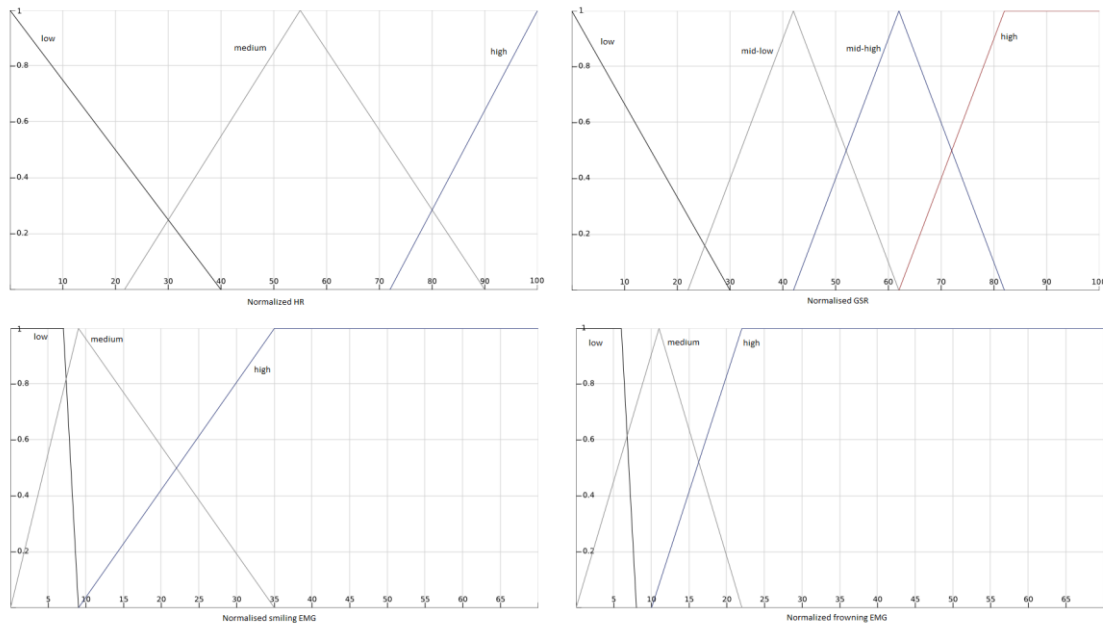


Figure 4 – Characteristics of the membership functions adapted from the work of Mandyk and Atkins (2007).

3.3. Rules

After converting the physiological values into linguistic terms, we used a set of rules, presented in Appendix A, to connect them with the values of arousal and valence, which were also categorized in linguistic terms. As we mentioned before, various studies have reported that GSR is linked to arousal. As such our rules reflect that when GSR rises so does arousal. However, since GSR can exhibit extreme highs and lows and its value tends to saturate over long periods we used HR to regulate it, meaning that if the values contradicted each other we would value HR more. For the valence, we used the EMG data collected from the player's brow and cheek. This was chosen since the actions of frowning (brow muscle) and smiling (cheek muscle) represent negative and positive emotions respectively. However, we also used HR as a secondary measure, in case EMG values were low for both the brow and cheek, since it was proven in some studies although debatable that it correlated with valence. Seeing as our game is not a game that entices fear we related a high HR to a positive emotion and a low HR to a negative one.

After determining the values for arousal and valence all that was left was to relate these values to emotions. This, however, is no easy task because there are no established guidelines and it may be hard distinguishing between different emotions (i.e. the same level of arousal and valence may relate to different feelings). To achieve this, we created our interpretation of the affect

grid (Russell, Weiss and Mendelsohn, 1989), presented on Fig 5, which is a scale designed for assessing emotions along the AV space.

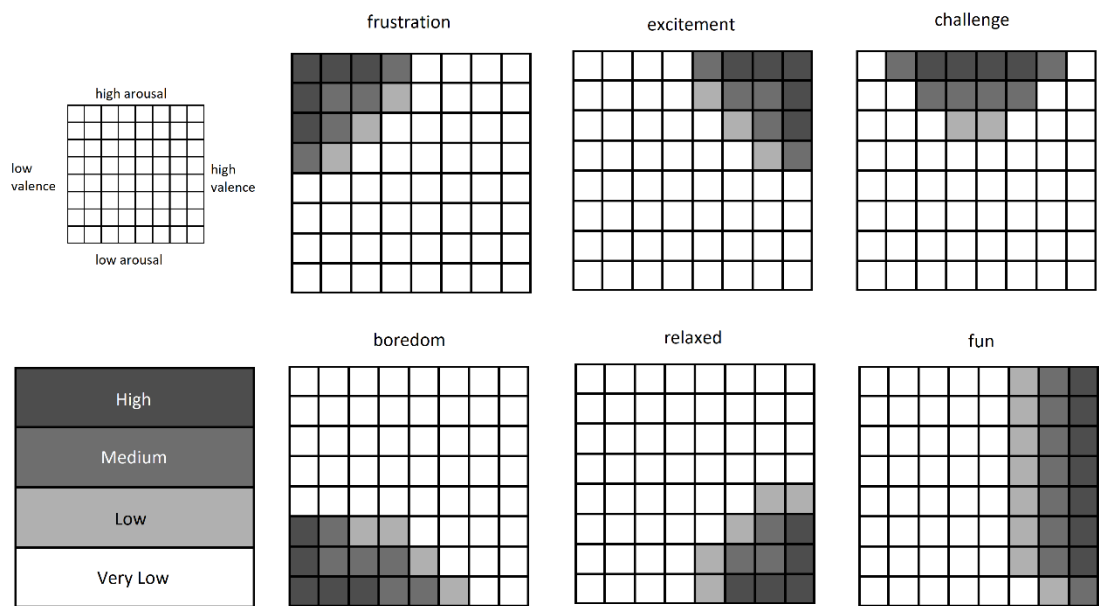


Figure 5 – Our interpretation of the affect grid for the different emotions that were relevant for our study

4. Methodological Approach

The main purpose of this study is to assess what are the more useful gameplay adaptations and biofeedback enhanced game mechanics in terms of impact on the user experience.

In order to better structure our approach, we devised the following sub-questions:

- Q1: Is a model based on fuzzy logic accurate enough to determine the player's emotional state and can it be calibrated in-game?
- Q2: Do the gameplay adaptations or emotional game mechanics have an impact on the player experience?
- Q3: How do direct and indirect biofeedback mechanics compare in terms of user preference and impact on their experience?
- Q4: Are different types of players, as determined by sex and gaming expertise, affected in a different manner by how they experience the game adaptations, either in terms of subjective or objective player experience?

Each of these questions will require us to evaluate different aspects of the game experience and to compare player's physiological data to their reported data.

For question 1 we compared the objective data gathered with the subjective data from player's post game questionnaires to check the accuracy of the player's emotional state.

In order to prove the assumption we made in question 2, we had to compare the play tests with control cases. To do so we compared the players' playthroughs to determine if the emotional mechanics had in fact an impact or not.

To answer question 3, we needed to have information on the player's preferences on the different game mechanics. This was achieved by having the game's emotional manager log the physiological data on the player experience and the game events. As a fallback method we also used a post-game questionnaire that gathered subjective information on the player's experience.

To compare players in terms of sex and game expertise we collect that information in the post-game questionnaire so we can later compare the physiological data gathered during the play tests thus answering question 4.

4.1. Experimental Constraints

Due to some of the gameplay aspects we wanted to test and our research questions some experimental constraints were bound to appear. We identified the following constraints:

- *Testing game balance:* Since we wanted to test whether the biofeedback mechanics were able to create a more balanced game, this study required us to have two gaming conditions (one with emotional mechanics and a control condition). Additionally, players could only play one of the conditions since the more the game is played the more proficient the player gets, making it difficult to determine how difficult the game actually was.
- *In-game calibration:* Monitoring a person's emotional state requires us to first calibrate the emotion recognition program. Doing this while in-game required us to create a first level where the player would experience the whole gamut of emotions the game had to offer, thus granting us with a player model relative to our game.
- *Gathering and using data:* In order to gather the player's physiological data and recognize the parts where the player was actually playing the game we had the game output this data together with specific game events. Although both versions of the game gather and output data only one uses it in real time which meant this functionality would have to be easily toggled in our game.

4.2. Game

Nightmares is an indie roguelite shooter build with the Unity game engine. We chose to create a roguelite game to further support the claim that biofeedback mechanics can be used on games that induce more discrete emotions (e.g. challenge, boredom, stress), as opposed to horror games that elicit strong emotions from the users (e.g. fear, anxiety).

Nightmares places the player in a world where the character is lost and wants to return home. Enemies however will make it difficult for him but with the guidance of a mysterious stranger the player is told more about the world he is in until the stranger finally betrays the player in the end. To reach the final confrontation the player will have to explore the different levels to find specific

objects which will allow him to continue, all while being assaulted by hordes of enemies which increase in difficulty as the player progresses.

The game's dialogue and plot are made to create some sense of empathy and sometimes amusement on the player while the combat tries to bring out the challenge and stress. However, our study only focused on balancing the challenge, stress, boredom and fun levels through the combat.

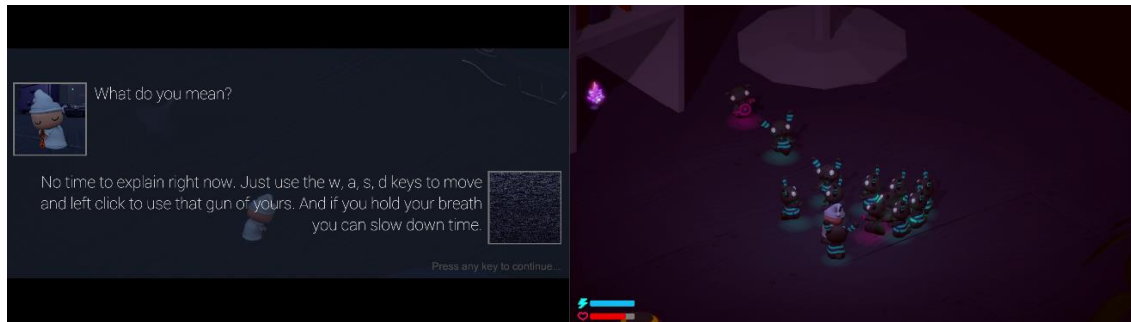


Figure 6 – Gameplay examples. On the left an example of in-game dialogue; on the right enemies surround the player creating stressful situations

The game is composed of 5 different levels including a tutorial. The tutorial serves both as a way to introduce the player to the game's story and mechanics while also calibrating the emotion recognition to the player. This is done by introducing the player to the game through funny dialogue and then putting him to the test increasing in difficulty until he finally "dies". The player then finds out he didn't actually die and was in fact transported to the 1st level by the mysterious character. The game progresses in difficulty as the player completes levels and was made purposefully very difficult by level 3, we hope to use this increase in difficulty to determine if the game balancing done with the emotional mechanics was effective.

In the next sections, we will discuss game's core game mechanics and how we used the biofeedback to adapt them. To conclude, we will present the game's architecture and how it was integrated with the Nexus10.

4.2.1. Game Mechanics

Nightmares was created by using a free sample project from the unity asset store and then adding extra content and new game mechanics on top. The features that follow are those that were adapted with the player's emotional state.

Enemy spawns

As a shooter, our game needed to determine where, when and how many enemies could appear in each level, as such we implemented spawner scripts and chose spawn locations for each level. Spawns were then generated during the game and modified in the biofeedback version according to the player's arousal.

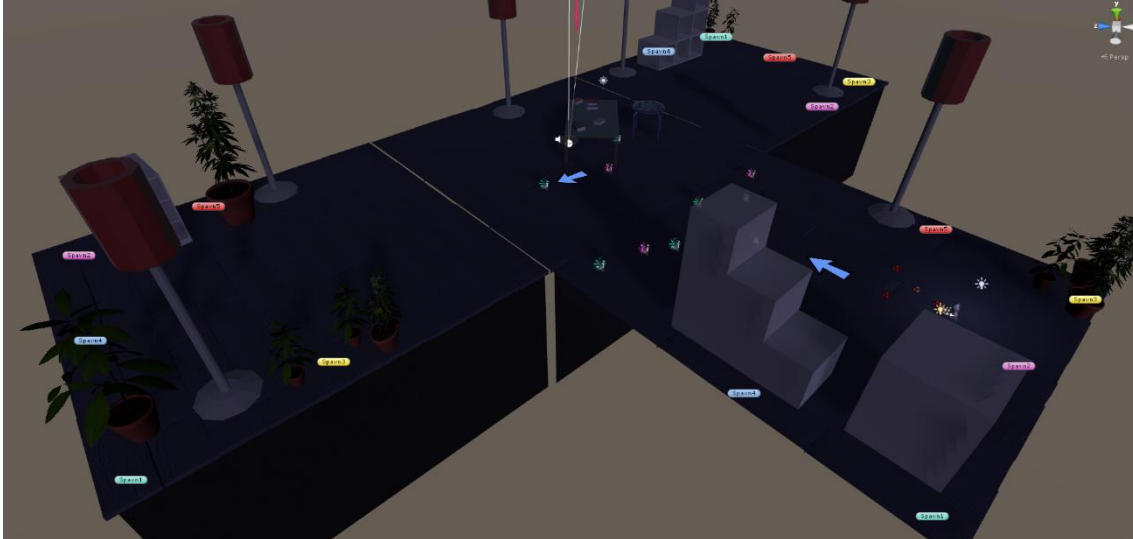


Figure 7 – Scene from unity showing the position of spawn points

Boredom spawn

An additional feature related to enemy spawns was implemented to avoid creating long periods without action. This boredom spawn would over time increase the probability of a spawn of enemies occurring if nothing had happened in the past ten seconds. In the biofeedback version, this probability was modified with the player's arousal and valence so that, only when the arousal and valence were low, the probability was high.

Light conditions

Although the game was not a horror game lighting was still an important way to control the game mood which we chose to keep darker. In our game, we chose to keep lighting to a minimum to simulate the effect of not knowing what came next. Lights were also adapted to the player's mood, creating a darker environment when the player was stressed and providing more light if the player maintained his cool.

Bullet time

As mentioned before the game was made intentionally difficult but we didn't want to leave the player with no way to fight back. A bullet time effect, where the player could slow down enemies and shots but still move at normal speed, was implemented as a direct biofeedback mechanic by breathing in and holding his breath (available in both the control condition and the emotional version). The

player could use this power for up to four seconds before having to recharge. In the emotional version of the game the feature was balanced by recharging more slowly unless the player was highly stressed.

Item drops

Another way to help the player was by having enemies drop items. These items could be either a health pack that restored some of the player's health or a damage boost that greatly increased the player's damage for a few seconds. By picking up the items the player could survive for longer periods of time and quickly dispose of any enemy. The drops were rare though and only increased in drop rate when the player was emotionally stressed, meaning a player with high arousal and low valence had a greater chance of getting an item drop than a player that was having fun or was calm.

Item magnet

We noticed in early alpha tests that, when the player was facing a large number of enemies, item drops were useless because they stayed too close to the enemies for the player to pick them up. To help the player in this matter we implemented this feature that brought the items to the player when he was in trouble. For the emotional version of the game being in trouble meant having very high arousal and low valence, whereas for the control version being in trouble meant having less than a quarter of his health remaining.

4.2.2. Game Architecture

Nightmares was fully developed using Unity and included a script we called emotion manager that served as an intermediary between the game logic and the raw physiological data. We had the Nexus-10 device reading the physiological data for the GSR, BVP, EMG and RSP channels and used the Biotrace+ software, which connected via Bluetooth, to pre-process the different signals. Our emotion manager then retrieved the information in real-time and used it to calculate the arousal and valence values of the player. The script was programmed as a singleton entity and was present throughout every game scene so we could easily access it when needed. Furthermore, the emotion manager was also responsible for logging the game events and physiological.

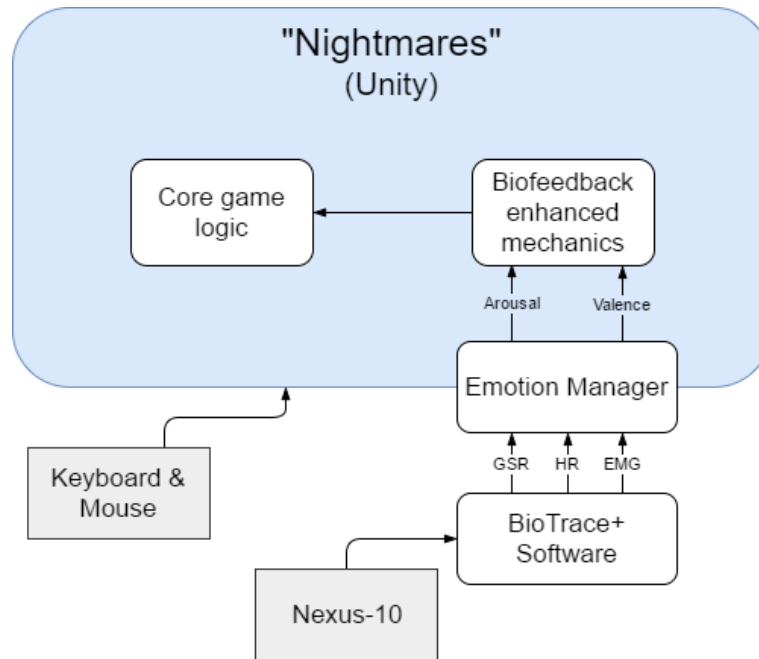


Figure 8 – Game architecture

4.2.3. Gaming Conditions

For our study, we created two gaming conditions whose results were used together to answer our research questions. In the condition with the emotional mechanics we used the player's measured levels of arousal and valence to make specific adaptations to some of the game elements. Our control condition still measured the player's physiological information and calculated their arousal and valence levels, however this was only used for analysis after the user had played the game. It is important to note that the player did not know in what conditions they were playing since we wanted to know whether the players realised that their emotions were being used to adapt the game or not.

With the emotional game condition, we aimed to create a game where the game balance was determined by the player's emotional state. Meaning the game would become easier if the player became too frustrated and harder if the player was too calm or bored. This way we could manipulate the game in order to challenge the player according to his skill level, whilst providing fun and challenging gameplay.

The second gaming condition was created as a control test for us to compare with the actual experiment. Without this condition we wouldn't be able to determine if the emotional mechanics had any effect on game balance and player enjoyment.

4.3. Experimental Protocol

In our study participants were first sorted between experienced players and non-experienced players and assigned in which condition they would be playing, the goal being to have half of the experienced players play the emotional condition while the other half played the control condition and the same for the non-experienced players. As the players were being fitted with the physiological sensors they were given a brief description of the experiment (leaving out details of the emotional mechanics) and then proceeded to play either one of the gaming conditions. After the experiment, the players were asked to complete a post-game questionnaire where we asked them about subjective feedback for the game experience and mechanics, as well as demographic information. Participants were also left alone to avoid any possible bias for questions and interaction was discouraged during gaming sessions to avoid creating bad readings of physiological data.

4.3.1. Calibration

Since our fuzzy system is supposedly adapted for the general audience the only calibration we needed to do was to record the player's highest and lowest values for each physiological variable, thus allowing us to normalise the current value and feed it to the fuzzy system. This was done in the first level which also acted as a tutorial, teaching the player the game mechanics and introducing him to the plot. To ensure with a high enough certainty that the player experienced a whole range of emotions though the calibration phase we introduce the game with some funny dialog and, after explaining the game basics, throw the player into an "unbeatable level" where the only way to progress is to eventually die. This way we could have emotions ranging from happy or content in the beginning to stressed and challenged as the screen fills with enemies and finally sad or frustrated when the character dies and maybe surprised when the game actually continues.

4.3.2. Tools

We had participants play the game on a laptop with Windows 10 whose screen had 15.6" and a resolution of 1366x768. To collect the physiological data, we used the Nexus-10 device in conjunction with the Biotrace+ software.

Additionally, we used sensors attached with Velcro straps to the player's index and middle fingers to measure his GSR while a sensor on his thumb read BVP values that Biotrace+ used to derive the HR. Finally, we used electrodes on the subject's face to measure EMG values at the cheek and brow muscles.

4.3.3. Participants

We had 12 participants (1 female) play our game, aged from 19 to 24. Unfortunately, due to not having enough female volunteers we won't be able to make significant comparisons between players in terms of sex.

Most participants had played a similar game (91.7%) with only 1 person having never played this type of game before. Nevertheless, gaming expertise was equally divided with 58.33% of the players reporting that they play games almost every day, which was also verified through visual observation. Finally, every participant revealed interest in playing games with new types of input.

4.4. Results

In the following sections we will discuss the results of our study by comparing the physiological values of players and their answers to our questionnaire between them. To be able to draw significant conclusions we segment our analysis into four categories based on what condition the participant played and their expertise level:

- Category 1: Experienced gamers playing on the emotional gaming condition.
- Category 2: Experienced gamers playing on the control condition.
- Category 3: Rookie gamers playing on the emotional gaming condition.
- Category 4: Rookie gamers playing on the control condition.

During our analysis we discovered proof supporting the validity of our emotion modelling and calibration. We also found evidence of significant differences between playing with and without emotional mechanics for the measured emotions (fun, challenge, boredom, frustration). In addition, we ran a detailed analysis of each individual to compare preferences between game mechanics and to evaluate the game difficulty control. Finally, we present the player's opinions as gathered with the questionnaire and their ability to identify the emotional mechanics.

4.4.1. Gaming condition impact based on biometric feedback

Before starting to divide our analysis between the different population groups it is important to note some aspects that were similar among every participant. One aspect was the fact that during the game cinematics arousal was generally low and valence was between mid and high values. Which is the consequence of the game being paused while the player reads somewhat funny lines. The second aspect being that, after the game end, arousal and valence rise meaning the player is happy for having played the game, which we did indeed notice when talking with players after the game. By noticing this we are able to shed some light on our first research question, if a fuzzy system can accurately model the player's emotional state, and although during the first level (i.e. calibration level) the data gathered is not accurate enough, we can say that for the next levels it certainly is.

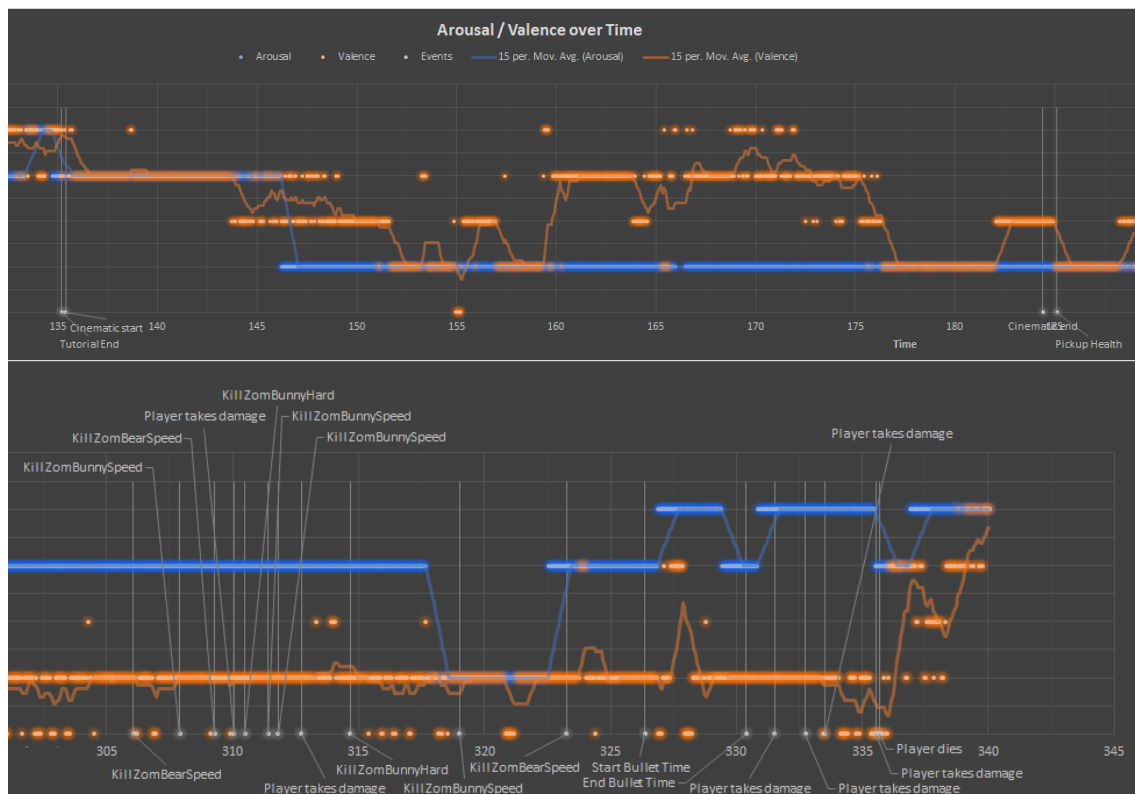


Figure 9 – Graphs for cinematic and game end. Top: graph for player 1 when reading initial dialogue for level 1; Bottom: graph for player 5 for his final fight and death

From the first graph, we can see that P1 ended the tutorial around 135s on an excited state and then calmed down while reading the first few lines on the dialogue with valence dropping to a mid-low level and arousal decreasing to a low value. Around the 160 seconds mark there is a sharp rise in valence with arousal remaining low possibly due to the player laughing at a joke. On the second graph, we notice that P5 is having an intense fight and stressing (low

valence and high arousal), however, after the player's death we notice an increase on the valence level due to the player's satisfaction from ending the game.

Regarding the impact of the biofeedback mechanics on the player's emotions, we must say that the analysis of the physiological data shows distinct patterns for players in each condition. After evaluation, it seemed that the emotional condition was able to provide a better flow, successfully alternating most of the time between stress, challenge, fun and calm emotions while reducing time spend on the third quadrant of the AV space (reducing boredom). The control condition, on the other hand, presented very long periods of the same emotional state, with the players being mainly in a bored state, however, since not enough time passed, the boredom spawn never triggered for any player in this condition, while for the emotional condition when long periods of boredom with no events happened the boredom spawn triggers most of the time.

In our game, the biofeedback mechanics not only tried to reduce the game's boredom but also tried to make the game more adaptable to the player's skill level. As it was said before the game was made to be especially difficult and probably not possible to complete in a first attempt in an attempt to measure how difficult the game was by using the player's progression (the farther he went the easier the game was for him). Not surprisingly no one completed the game or even reached the final level. What was somewhat surprising is that every player except P12, who fits into category 1, reached the second game level (P12 reached the early stages of level 3). This however doesn't mean the game wasn't more adapted in terms of difficulty for the emotional condition, in fact, we noticed an increased number of drops on players who showed difficulty, and less drops for skilful players when playing the emotional condition.

the subjective reports of players after playing the game, as well as, an analysis of the players' preferences on the different game mechanics.

4.4.2. Player preferences and analysis

To better understand what was the players' opinion of the game and their preferred mechanics we had them answer a short questionnaire. The first point to mention is that when rating the game experience eleven out of twelve participants rated the game as fun, even those that appeared bored on the physiological metrics. This could be due to the fact of the experience, as a whole, being fun, some small episode during the game being enjoyable or simply due to issues discussed on the part on Subjective PEM, such as self-deception. When rating their experience players also reported it to be challenging and sometimes frustrating, which is normal due to the high difficulty level of the game. Another understandable aspect of the questionnaire was everyone rated the game's difficulty normal or higher (on a scale of 1 to 5 with 1 being very easy and 5 being very hard) with 66.7% rating it hard or very hard. Again here, although everyone found the game to be fairly hard, we can see the subjectivity of the scale since nearly everyone got to the same point in the game (level 2). That didn't stop 4 people from rating the game's difficulty as normal and 2 as very hard. Showing again the unreliability of Subjective PEM.

To understand what mechanics were more useful in creating a better game experience we wanted to directly ask the players what were their preferred mechanics (while keeping them in the dark on how they actually worked). The players were allowed to choose more than one preferred mechanic if they so desired, although we didn't ask them to order them. Not surprisingly the preferred mechanic was the *Bullet Time*, with 9 votes, followed by *Boredom Spawn*, with 7 votes. The other mechanics with a relevant number of votes were *Light Conditions* and *Item Magnet*, with 5 and 4 votes respectively. The most popular mechanic is also the easiest to explain and to verify with the physiological data. As it is the only direct biofeedback mechanic it is the only one the players have total control on, which, as we discussed in the section on affective gaming, is usually preferred by the players.

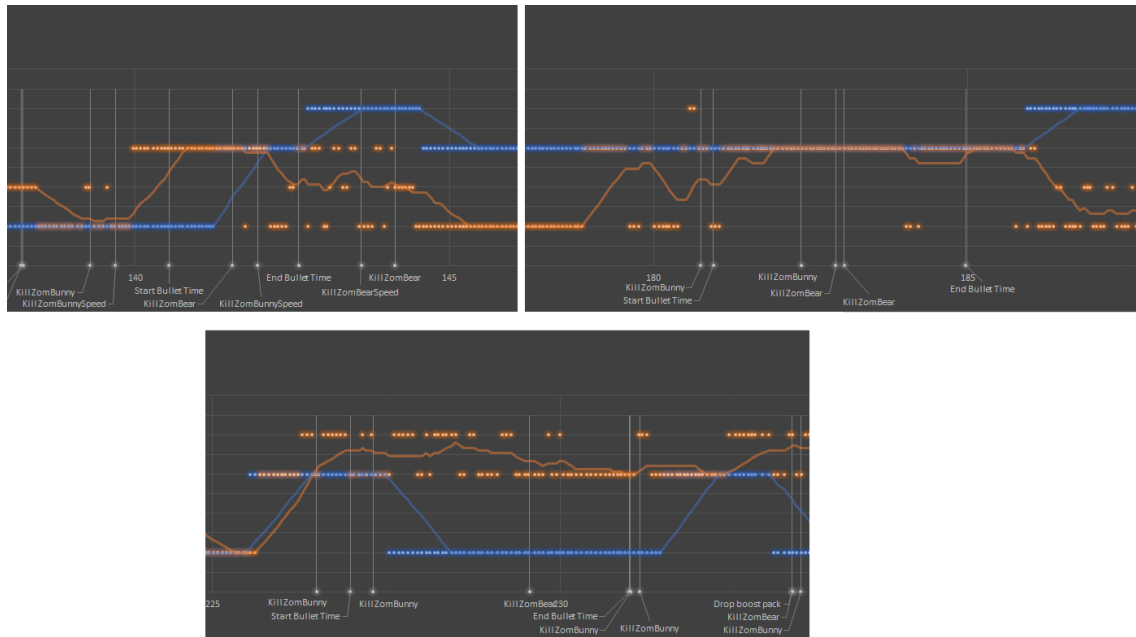


Figure 11 – Graphs showing usage of bullet time mechanic. P11 using bullet time resulting in an increase on valence (top) and P1 using bullet time to relax for a moment resulting in a decrease in arousal

The second preference is trickier to explain since upon further analysis we discovered that not every player experienced the *Boredom Spawn*. Participants may have chosen this answer as a consequence of self-deception (i.e. thinking that the event happened during the game when in fact, it didn't) or because the premise behind it sounded appealing (i.e. thinking this would be a good feature in a game even though they didn't experience it).

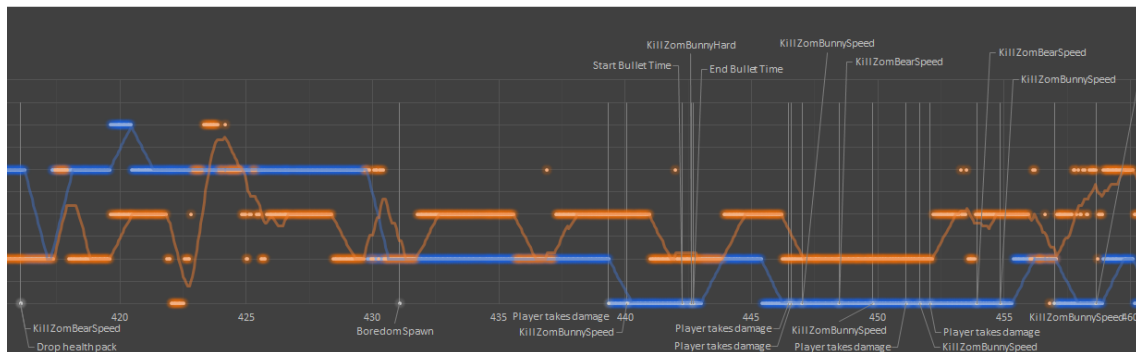


Figure 12 – Graph during boredom spawn mechanic. Boredom spawn triggers 15 seconds after P9's last kill when arousal and valence drop to low levels, meaning he's bored, which results in more enemies appearing causing some spikes of arousal and raising his valence to a medium level.

The same is true for the *Light Conditions* since some of the players that reported liking the mechanic didn't experience it at all, as it wasn't present in the control version of the game. This feature's preference is also impossible to assess with the physiological data since it reflects the player's emotional state and can easily pass unnoticed during gameplay. The *Item Magnet* on the other hand,

is easy to explain as it represents a mechanic that exists simply to help the player out of a sticky situation (i.e. the players like the mechanic because it exists only to help them). Although players had no idea of how it worked many reported it helping them with P9 stating after the game:

“I was low on health and then saw boxes flying all the way across the map to heal me.” (P9)

5. Conclusions and Future Work

5.1. Summary of Research and Findings

According to recent research immersion is a key aspect in videogames and a deciding factor in the overall game experience. Furthermore, work in the field of affective gaming has proven several times that biofeedback can be used to enhance the immersive experience, therefore creating a better gaming experience.

Related work covers a wide range of subjects from creating Player Experience Models to determine the user's emotional state to direct and indirect biofeedback and their usage within games. Our work focused on a specific type of PEM (objective) and used a fuzzy system to model the player's emotional state with the goal of using those emotions to adapt a game created by us, thus creating what we called emotional game mechanics.

The study we conducted provided evidence supporting the validity of the fuzzy system and emotion modelling implemented, while also showing that the calibration for the physiological data can be done in game, thus removing the need for a calibration before the game and making it easier to use our model in the current game industry. Despite having collected positive results time was one of our constraints as was the number of participants, as such, longer playtests and with a larger population must be conducted before this can be affirmed with absolute certainty and transferred to the industry.

Upon analysing the physiological values of players, we found significant differences for each gaming condition. Players in the emotional condition showed a better emotional flow, and their emotions alternated between the ones that were targeted (i.e. fun, challenge, relax), while time spent on other (undesired) emotions was reduced (i.e. boredom).

Additionally, the emotional condition was able to provide players of different skill levels with custom experiences as the game provided help for players in need, proving that not only can biofeedback can provide a unique experience but also that it can have a purpose (other than creating the unique experience) such as controlling the game's difficulty. Nonetheless, we must point out that players experience the game differently and differences were found when analysing the players in terms of gaming expertise, meaning that a game designer should take this into account when designing the game and plan accordingly. Furthermore, this could apply to players with different demographics (i.e. distinguished by sex, age, nationality, etc.), however, due to the lack of participants we weren't able to verify this hypothesis and we recommend further research on this topic.

As we see it, the main obstacle for biofeedback games after the work done by this study is the availability of the required hardware, since it isn't feasible to have players place electrodes on their face and attach agility impairing sensors to their fingers each time they want to play a game. Nevertheless, we feel that soon these issues will be overcome due to the interest shown in these technologies by the industry's giants.

Even though we consider the study to be a success and that it shed some light on issues left unanswered by previous works, we know that there is room for improvement and that more work should be done before using this technology on commercial games.

5.2. Future work

We feel that with the success of our work and provided that the appropriate hardware is used the methods used in this study could be used in a commercial game to improve the game's quality. However, despite the favourable outcome of our work, there are some aspects that could be improved.

Regarding the game there is a lot of room for further development in terms of game design and more biofeedback mechanics. As we discussed previously one of our goals was to manage the game's difficulty and evaluate how the players fared by looking at how far they got into the game. Revamping the game's design, by adding more levels for example and scaling the game's difficulty more progressively, could provide us with better information how hard the game was to the players. This would require a bigger team as designing a game is a multidisciplinary process, involving artistic design, sound design which was not the focus in this thesis. Also, adding more content, like weapons or allowing the player to move in the y axis (i.e. to jump, climb and fall), and linking these features to emotional mechanics is always useful since another goal was to determine which mechanics have a greater impact on the player. Furthermore, adding an artificial intelligence that could keep track of the preferred events of players and decide what events to present them based on their emotional state could also be a great improvement.

When it comes to the study, the main thing we point out is the need for a bigger number of participants and with more evenly distributed demographics as this was the main obstacle stopping us from drawing more conclusions. Additionally, we felt a need for a more complete post-game questionnaire, since the questions we asked turned out to be somewhat superficial at times, providing incomplete or inconclusive results. Furthermore, in a perfect situation every playtest would be done in an isolated environment to minimise any bias effect. Finally, something that can be done in a future study would be to ask the general audience to list their preferred game mechanics as to later implement them as emotional mechanics and check if the players thought it was an improvement.

Appendix A

Rules for converting physiological data into arousal-valence space. The following 17 rules were used together with the membership functions to convert GSR, HR, EMGsmiling, and EMGfrowning into arousal and valence:

1. If (GSR is high) then (arousal is high)
2. If (GSR is mid-high) then (arousal is mid-high)
3. If (GSR is mid-low) then (arousal is mid-low)
4. If (GSR is low) then (arousal is low)
5. If (GSR is low) and (HR is high) then (arousal is midlow)
6. If (GSR is high) and (HR is low) then (arousal is midhigh)
7. If (EMGfrown is high) then (valence is very low)
8. If (EMGfrown is mid) then (valence is low)
9. If (EMGsmile is mid) then (valence is high)
10. If (EMGsmile is high) then (valence is very high)
11. If (EMGsmile is low) and (EMGfrown is low) then (valence is neutral)
12. If (EMGsmile is high) and (EMGfrown is low) then (valence is very high)
13. If (EMGsmile is high) and (EMGfrown is mid) then (valence is high)
14. If (EMGsmile is low) and (EMGfrown is high) then (valence is very low)
15. If (EMGsmile is mid) and (EMGfrown is high) then (valence is low)
16. If (EMGsmile is low) and (EMGfrown is low) and (HR is low) then (valence is low)
17. If (EMGsmile is low) and (EMGfrown is low) and (HR is high) then (valence is high)

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